Is Wheat Kernel Size and Shape Related to Flour Yield?

Mark E. Sorrells

Department of Plant Breeding & Genetics

Cornell University

Cornell University

Department of Plant Breeding & Genetics

Celebrating 100 Years of Crop Improvement

2007 Cornell Plant Breeding Centennial Symposium – July 26-28

Presentation Overview

- What affects milling quality?
- Previous work
- Recent QTL studies of 3-D image analyses
- Association Mapping of Kernel Size and Milling Quality in Soft Winter Wheat Cultivars

New York Soft White Winter Wheat Varieties

Factors affecting Milling Quality

- Proportion of Endosperm:
  - Kernel size, shape, embryo size, seed coat (bran) thickness, shriveling
- Friability and Endosperm Separation:
  - Hardness, fiber content, crease depth and width, cell wall thickness in sub aleurone
- Proportions of Major Constituents
  - Endosperm - 81-83%
  - Embryo + Scutellum - 2-5%
  - Pericarp + Testa + Aleurone - 14-16%

Previous Reports: Traits vs. Milling Yield

- Kernel size - Mixed, weak to strong relationship depending on the study
- Test weight - Weak to moderate correlation
- Shape , embryo size, seed coat (bran) thickness - ?
- Shriveling - Significant correlation
- Hardness - Not significant within class
- Crease depth and width -No apparent relationship
- Cell wall thickness in sub aleurone - ?

Potential Undesirable Correlations

- Kernel Size and Shape:
  - Uniformity vs. grain yield - % tertiary kernels reduced
  - Size vs. Roundness - Larger kernels seem to be proportionately longer
- Reduced Embryo Size
  - Poorer emergence, seedling vigor

Recent Studies

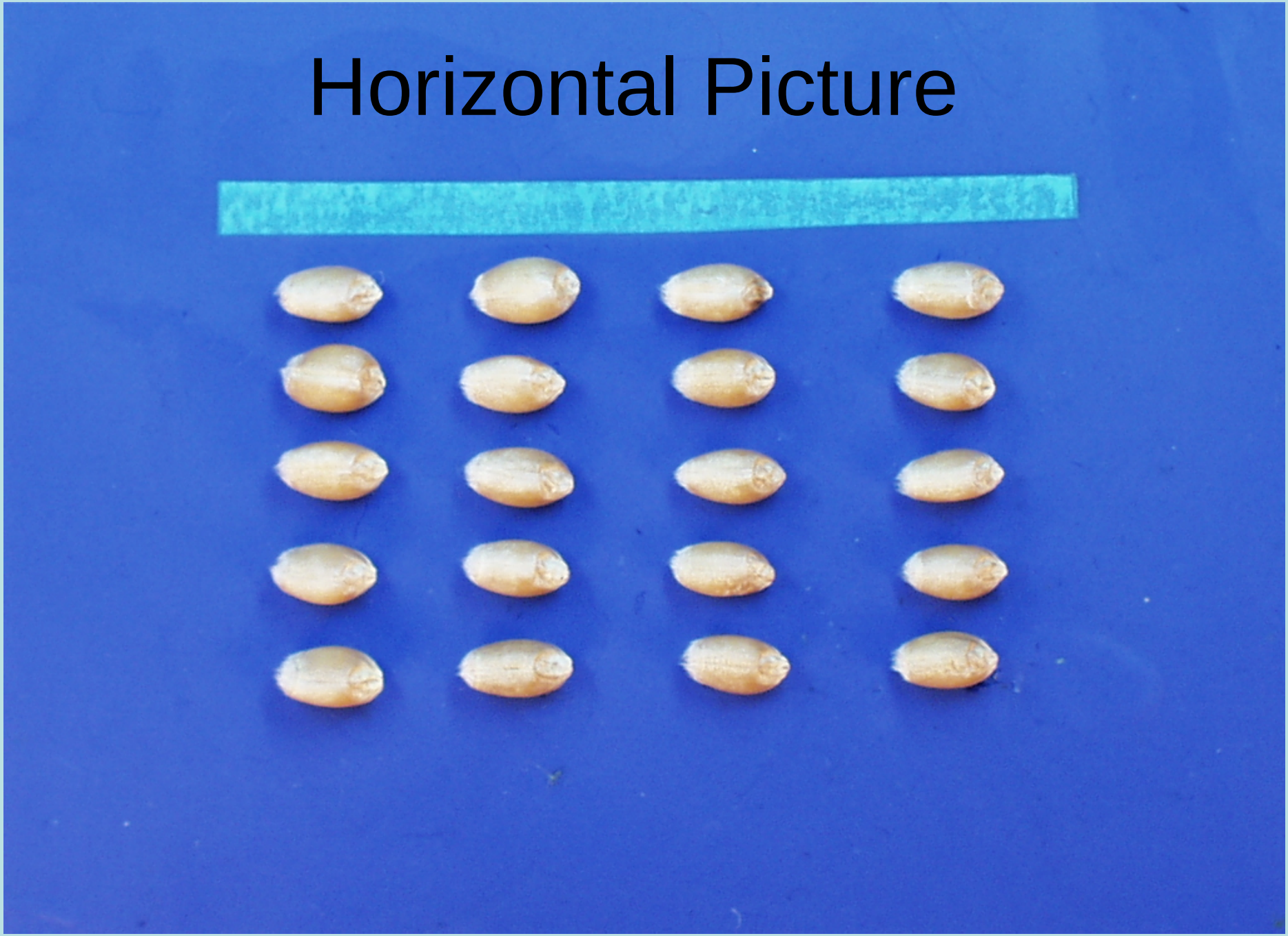
- Breseghello, F., P.L. Finney, C. Gaines, L. Andrews, J. Tanaka, G. Penner, and M.E. Sorrells. 2005. Genetic loci related to kernel quality differences between a soft and hard wheat cultivar. Crop Sci. 45:1685-1695.
  - 9 Reed x Grandin (Soft x Hard): Three locations - Canada, California, New York
- Breseghello, F., and M.E. Sorrells. 2006. Association mapping of kernel size and milling quality in wheat (*Triticum aestivum* L.) cultivars. Genetics 172:1165-1177.
  - 95/149 elite soft winter wheat cultivars from the Northeastern US: Mostly recent releases, representing 35 seed companies / institutions
  - 93 SSR loci: 33 on 2D, 20 on 5A, 9 on 5B, 31 on 16 other chromosomes
- Breseghello, F., and M.E. Sorrells. 2007. QTL analysis of kernel size and shape in two hexaploid wheat mapping populations. Field Crops Res. In press.
  - Reed x Grandin (Soft x Hard) and Synthetic x Opata (ITMI) populations

Digital Image Analysis of Wheat Kernels

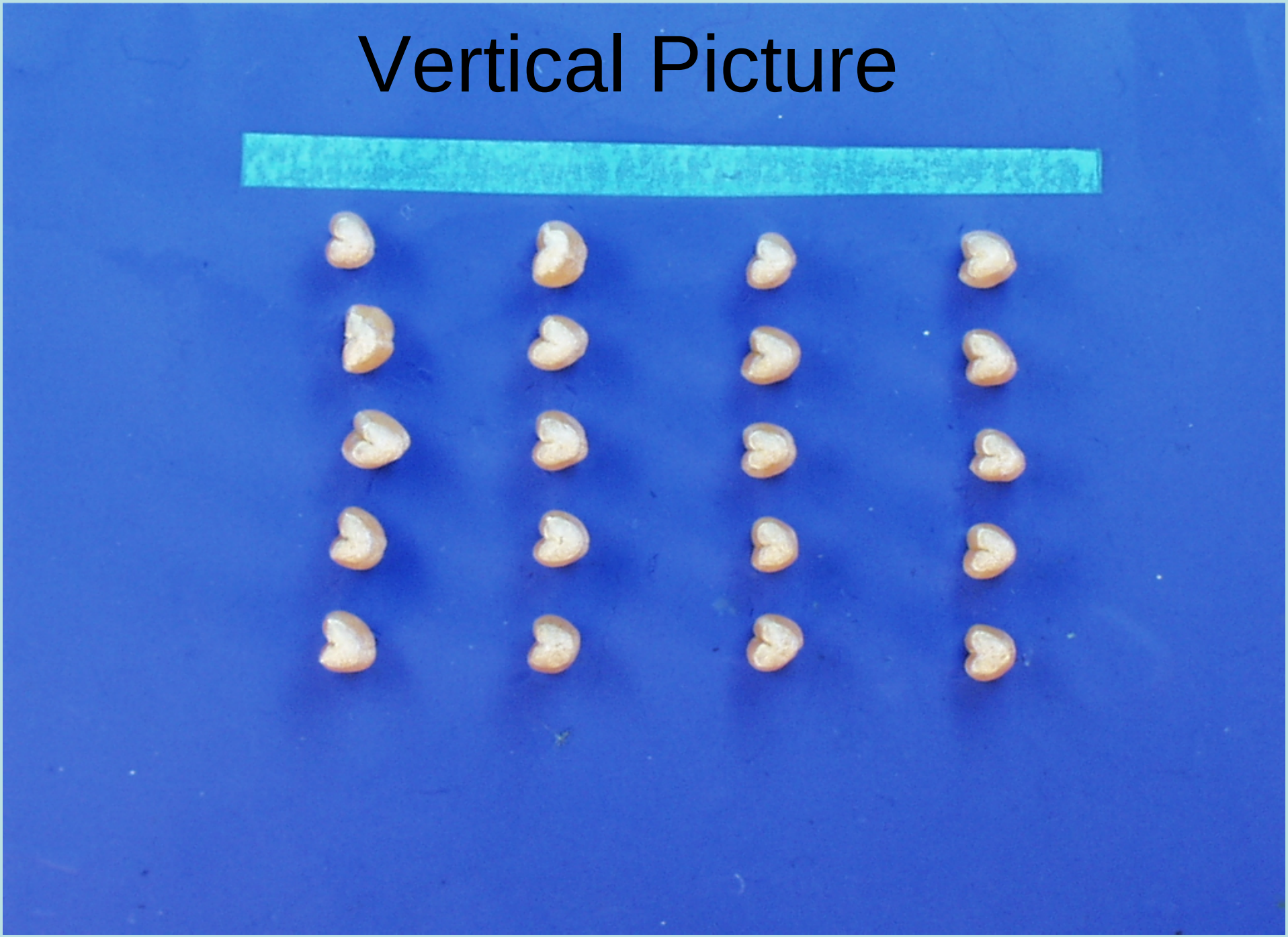
Flavio Breseghello

Grain morphology traits as targets for indirect selection for wheat milling quality in early generations

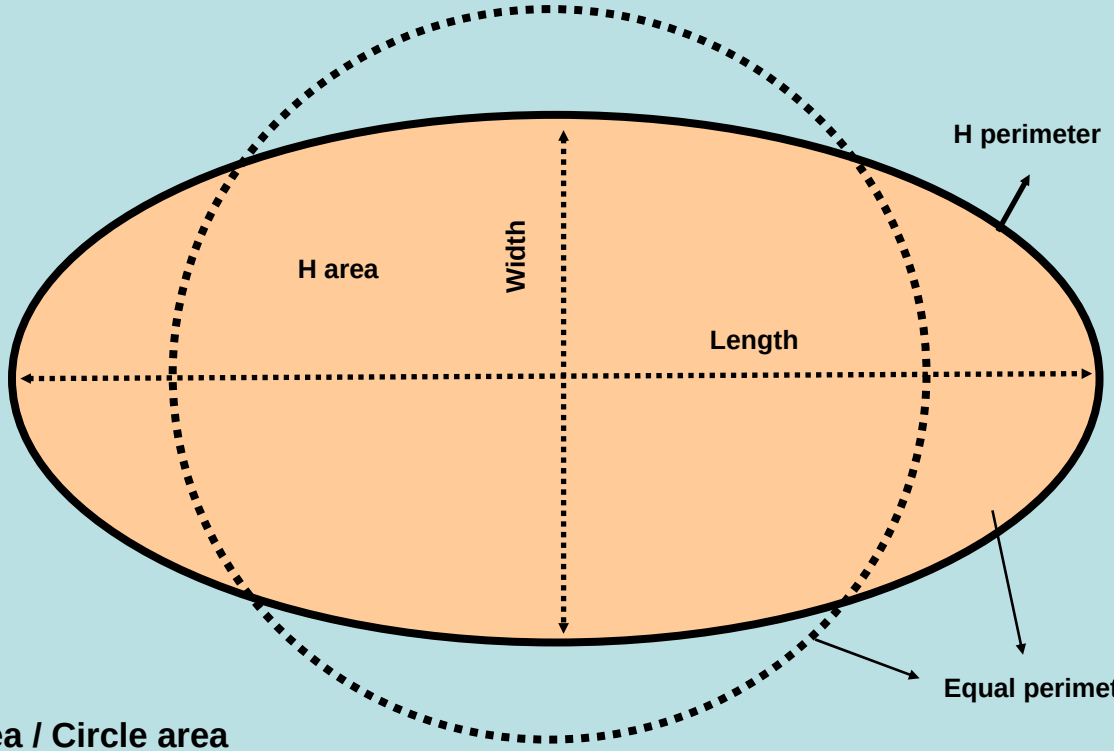
Horizontal Picture



Vertical Picture

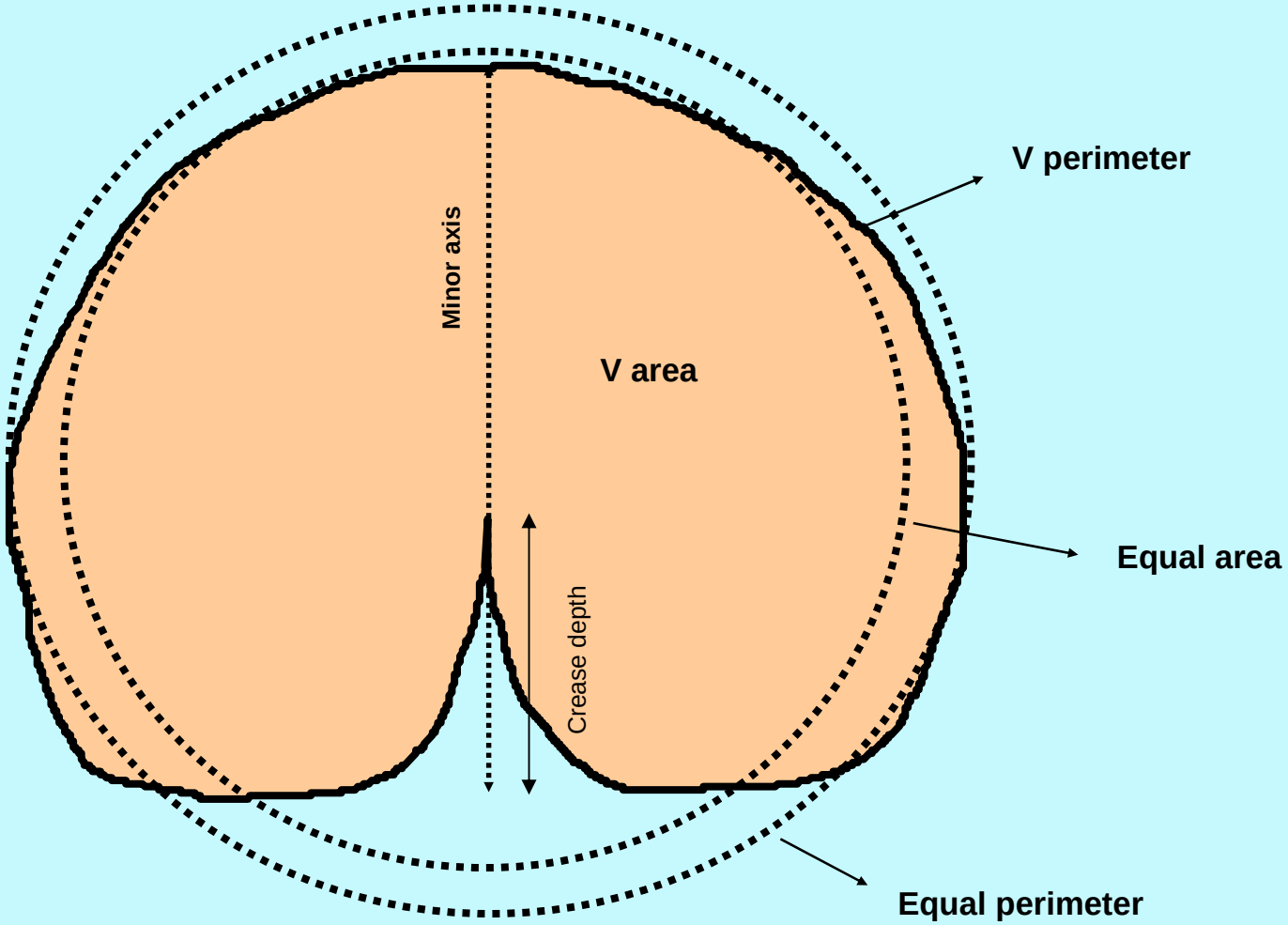


Horizontal Picture



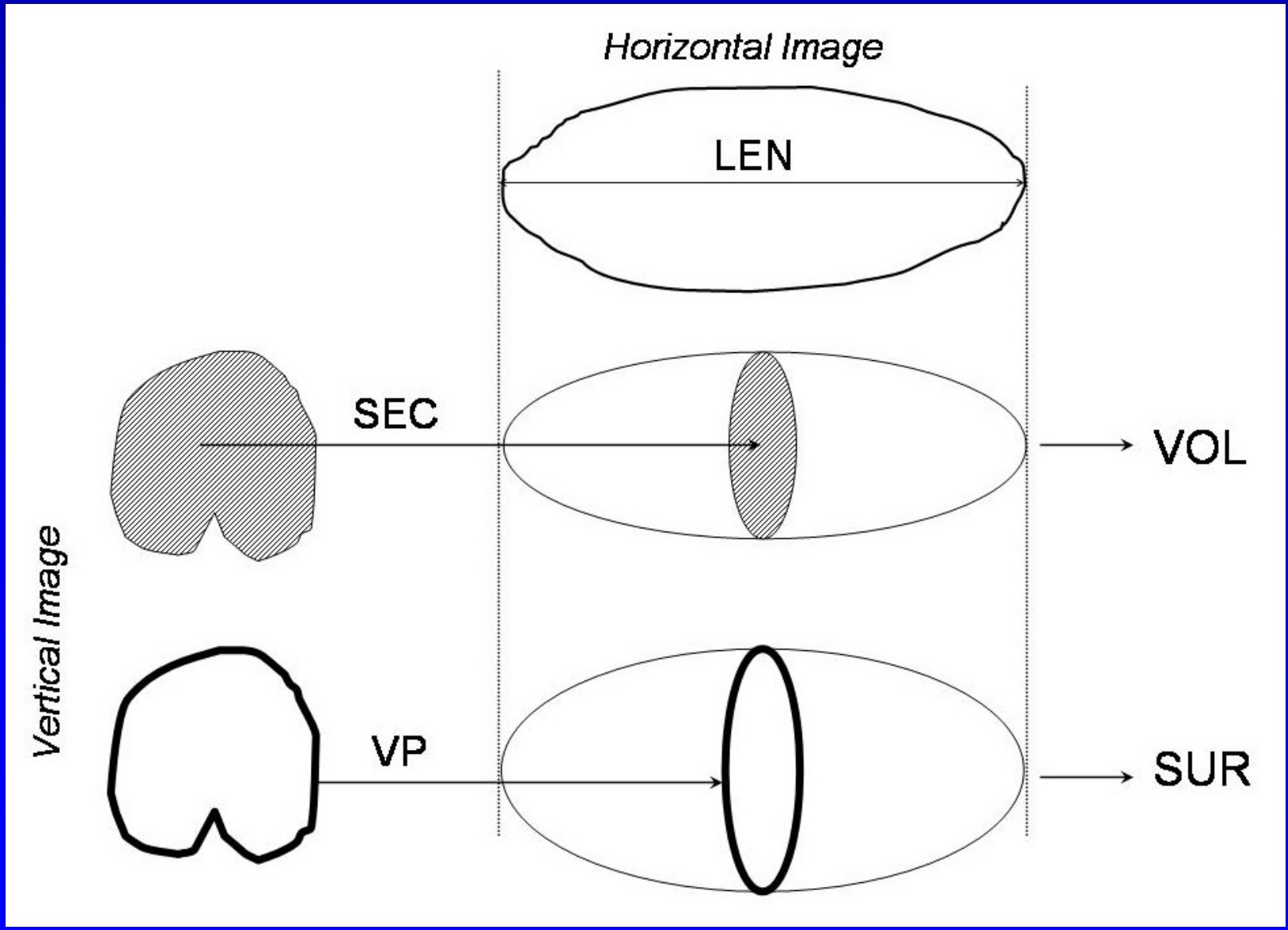
HSF: H area / Circle area

Vertical Picture



Volume = Spheroid based on equal-area circle
VSF = V area / area of equal-perimeter circle
Surface = Spheroid based on equal-perimeter circle
Flatness = Width / Minor axis

Surface & Volume Spheriod Scheme

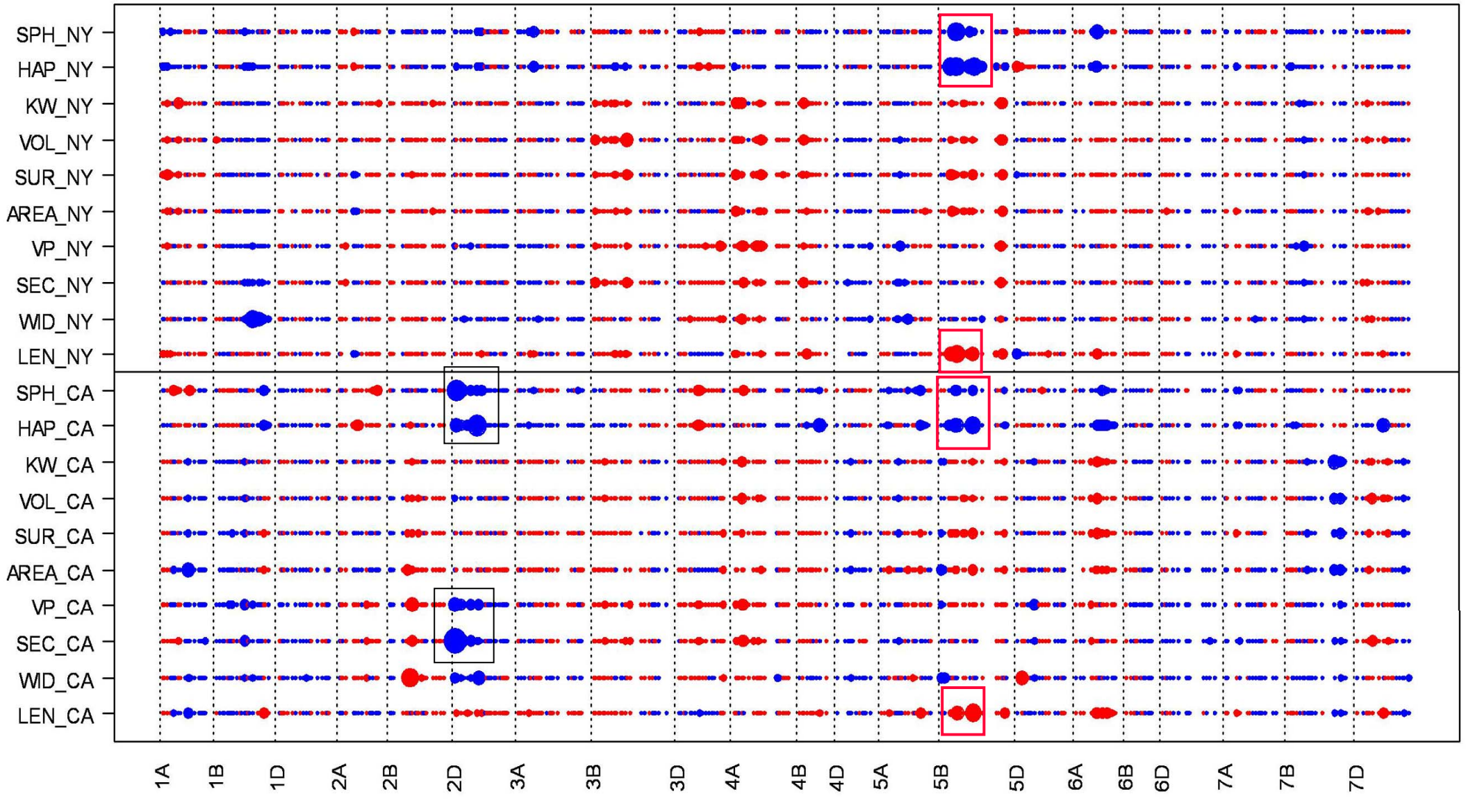


http:mathworld.wolfram.com/Spheriod.html

QTL Comparative Plot of Seed Size and Shape

(Single marker regression)

Synthetic x Opata



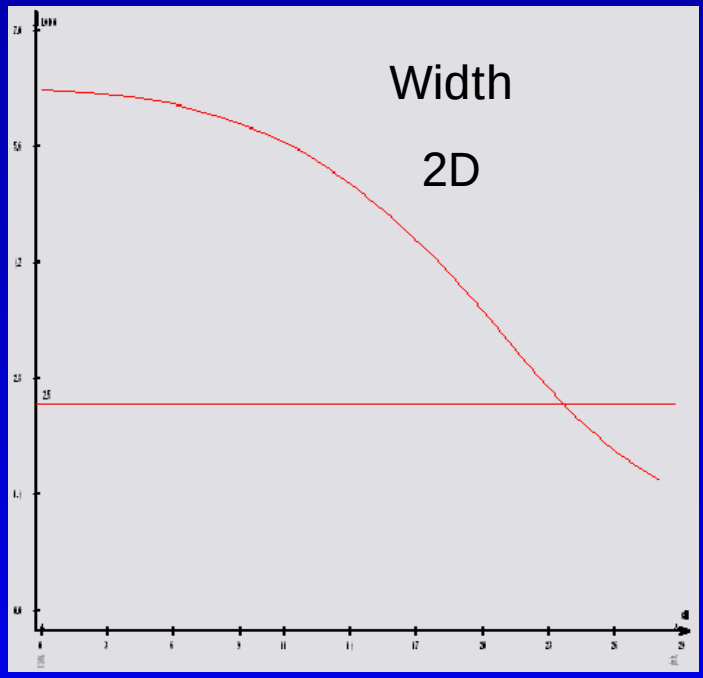
Association Analysis

Methods

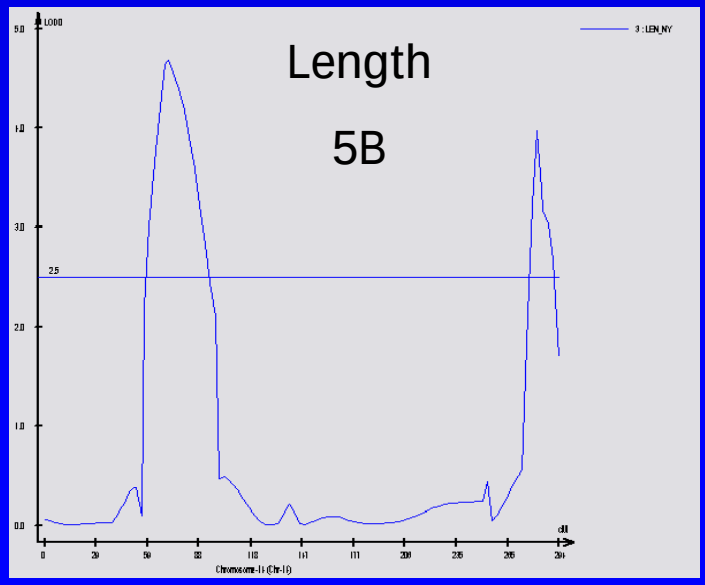
- Population Structure: 36 “unlinked” SSR markers - *TASSEL* - *Structure* without admixture, *SPAGeDi* (Hardy & Vekemans) program for Kinship
- Association Analysis: *R* stats package *lme* used to analyze Linear mixed-effects model with marker as fixed effects (selected from previously identified QTL regions) and subpopulations or Kinship as random effects (no obvious differentiating characteristics)
- Jianming Yu, Gael Pressoir, et al. (2006) A Unified Mixed-Model Method for Association Mapping Accounting for Multiple Levels of Relatedness *Nature Genetics 38:203-208*

Previous QTL information

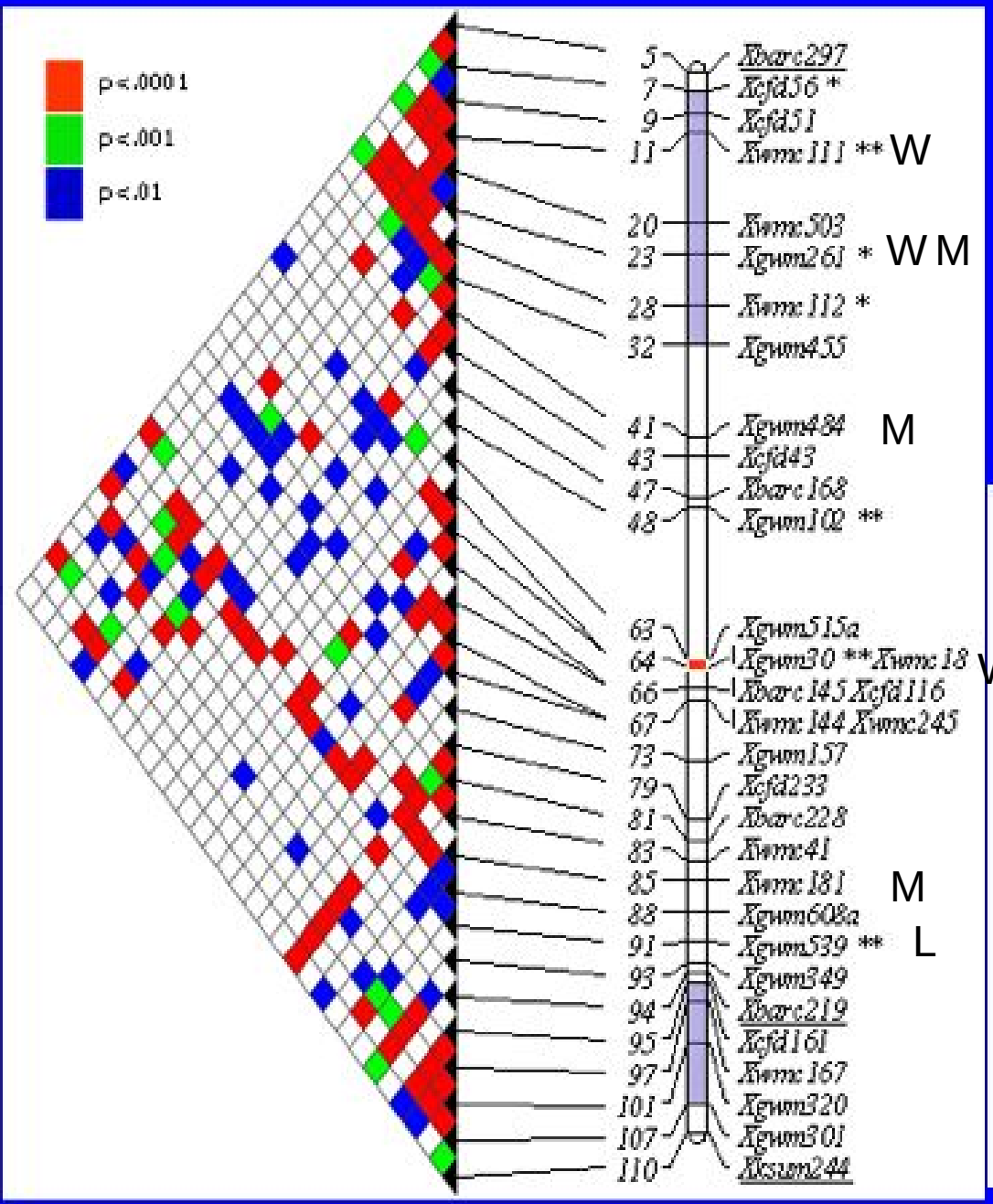
- Doubled-Haploid Population AC Reed x Grandin
  - QTL for kernel width near *Xwmc111*, *Xgwm30*, *Xgwm261* and length near *Xgwm539*
  - QTL for friability, ESI, and flour yield near *Xgwm261*, *Xgwm484*, *Xwmc181*, respectively.



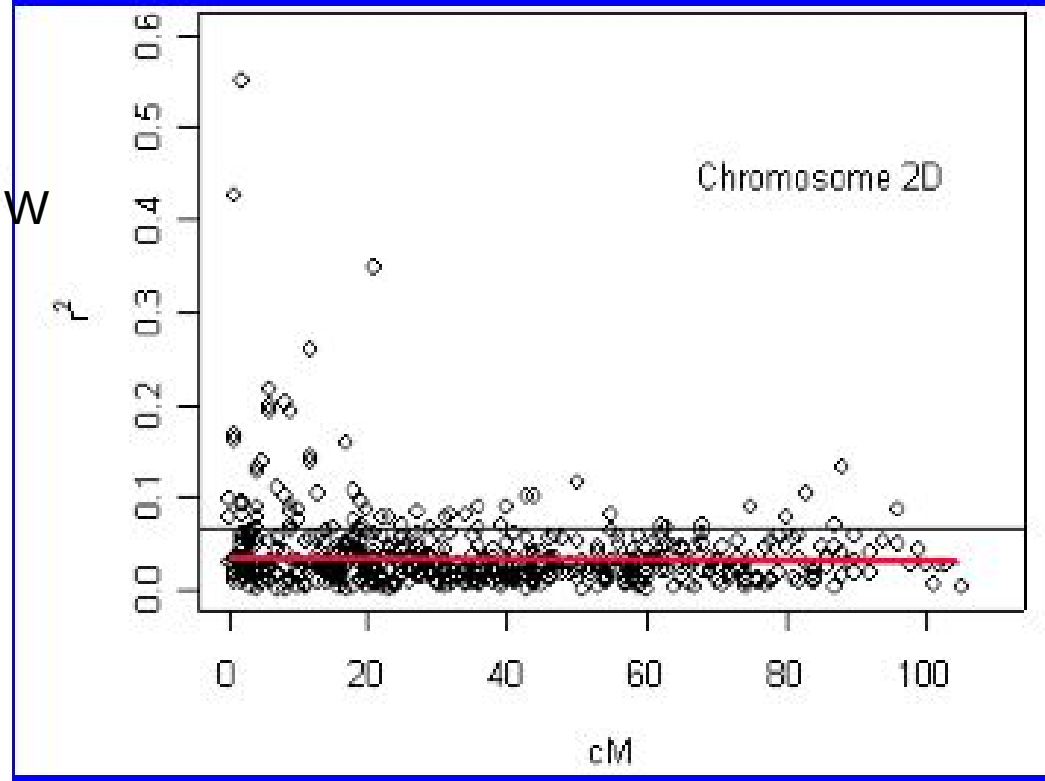
- Recombinant Inbred Population Synthetic W7984 x Opata
  - QTL for kernel weight, area, length and width on 5A and 5B.
  - QTL on 5A for friability.
  - QTL on 5B for flour yield, ESI, friability, and Break-flour yield.



Linkage Disequilibrium: Chromosome 2D



Significant LD was below 1 cM



Loci Associated with Kernel Size & Shape (p-values corrected for multiple testing)

Chromosome 2D

Agreed with QTL in Reed x Grandin

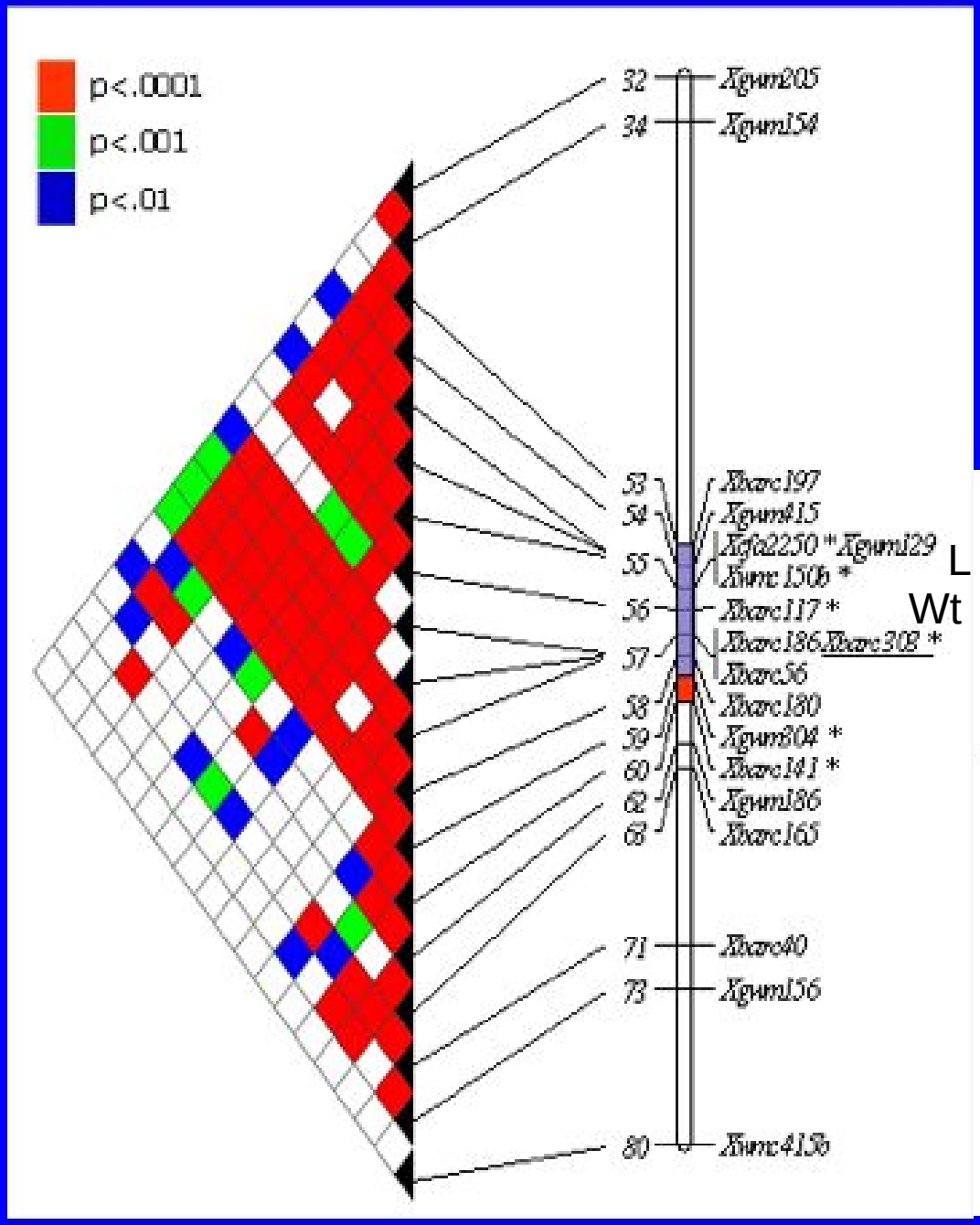
Kernel Size

Locus		Weight		Area		Length		Width	
cM	Name	NY	OH	NY	OH	NY	OH	NY	OH
7	*Xcfd56*	0.069	0.160	0.012	0.119	0.076	0.031	0.000*	0.252
11	*Xwmc111*	0.005	0.020	0.005	0.108	0.003’	0.107	0.000*	0.000**
23	*Xgwm261*	0.145	0.016	0.019	0.009	0.027	0.009	0.058	0.001*
28	*Xwmc112*	0.012	0.057	0.047	0.120	0.480	0.367	0.001*	0.024
64	*Xgwm30*	0.081	0.862	0.053	0.848	0.312	0.820	0.000**	0.212
91	*Xgwm539*	0.042	0.038	0.030	0.039	0.001*	0.005	0.290	0.334

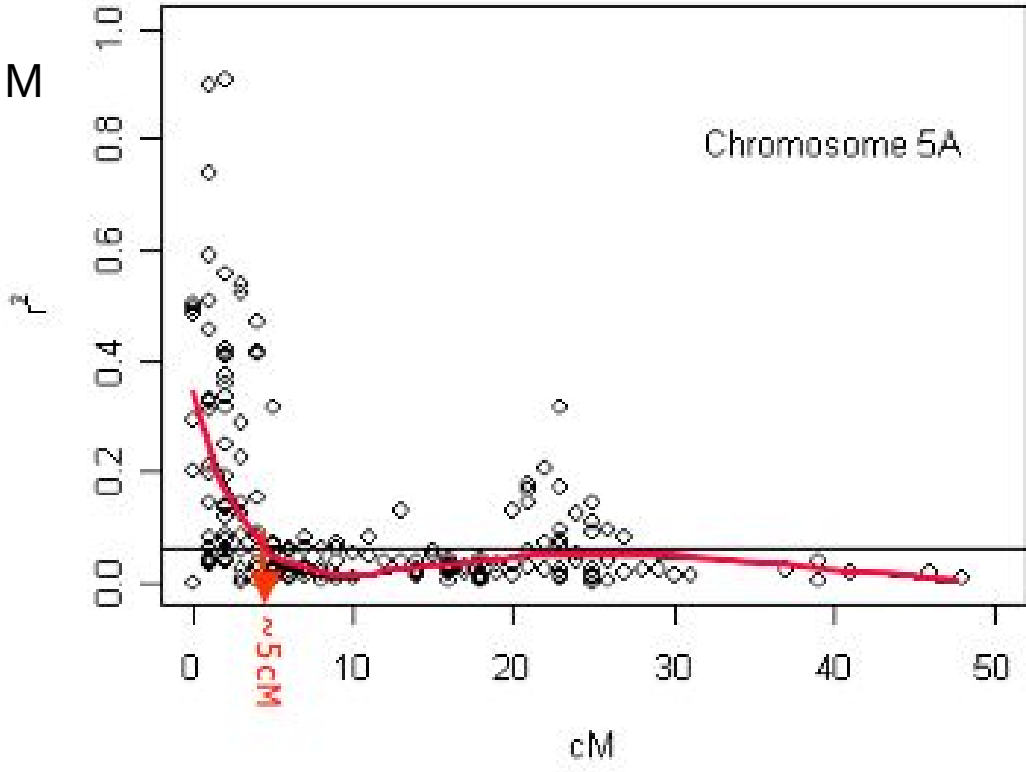
Milling Quality

cM	Locus	Milling	Flour Yield	ESI	Friability	Break-Flour
23	*Xgwm261*	0.008	0.052	0.019	0.003*	0.523
41	*Xgwm484*	0.022	0.039	0.003*	0.130	0.886
85	*Xwmc181*	0.003*	0.003*	0.007	0.006	0.607

Linkage Disequilibrium: Chromosome 5A



Significant LD extended for 5 cM



Loci Associated with Kernel Size & Shape (p-values corrected for multiple testing)

Chromosome 5A

Agreed with QTL in M6 x Opata

Kernel Size

Locus		Weight		Area		Length		Width	
cM	Name	NY	OH	NY	OH	NY	OH	NY	OH
55	*Xcfa2250*	0.021	0.007	0.044	0.014	0.014	0.002*	0.637	0.649
55	*Xwmc150b*	0.002*	0.003	0.003	0.005	0.009	0.002*	0.093	0.429
56	*Xbarc117*	0.009	0.002*	0.021	0.005	0.118	0.022	0.044	0.039
60	*Xbarc141*	0.631	0.037	0.232	0.024	0.038	0.002*	0.852	0.863

Milling Quality

cM	Locus	Milling Score	Flour Yield	ESI	Friability	Break-Flour Yield
55	*Xcfa2250*	0.010	0.029	0.047	0.002*	0.081

Loci Associated with Kernel Size & Shape (p-values corrected for multiple testing) Chromosome 5B

Agreed with QTL in M6 x Opata

Kernel Size

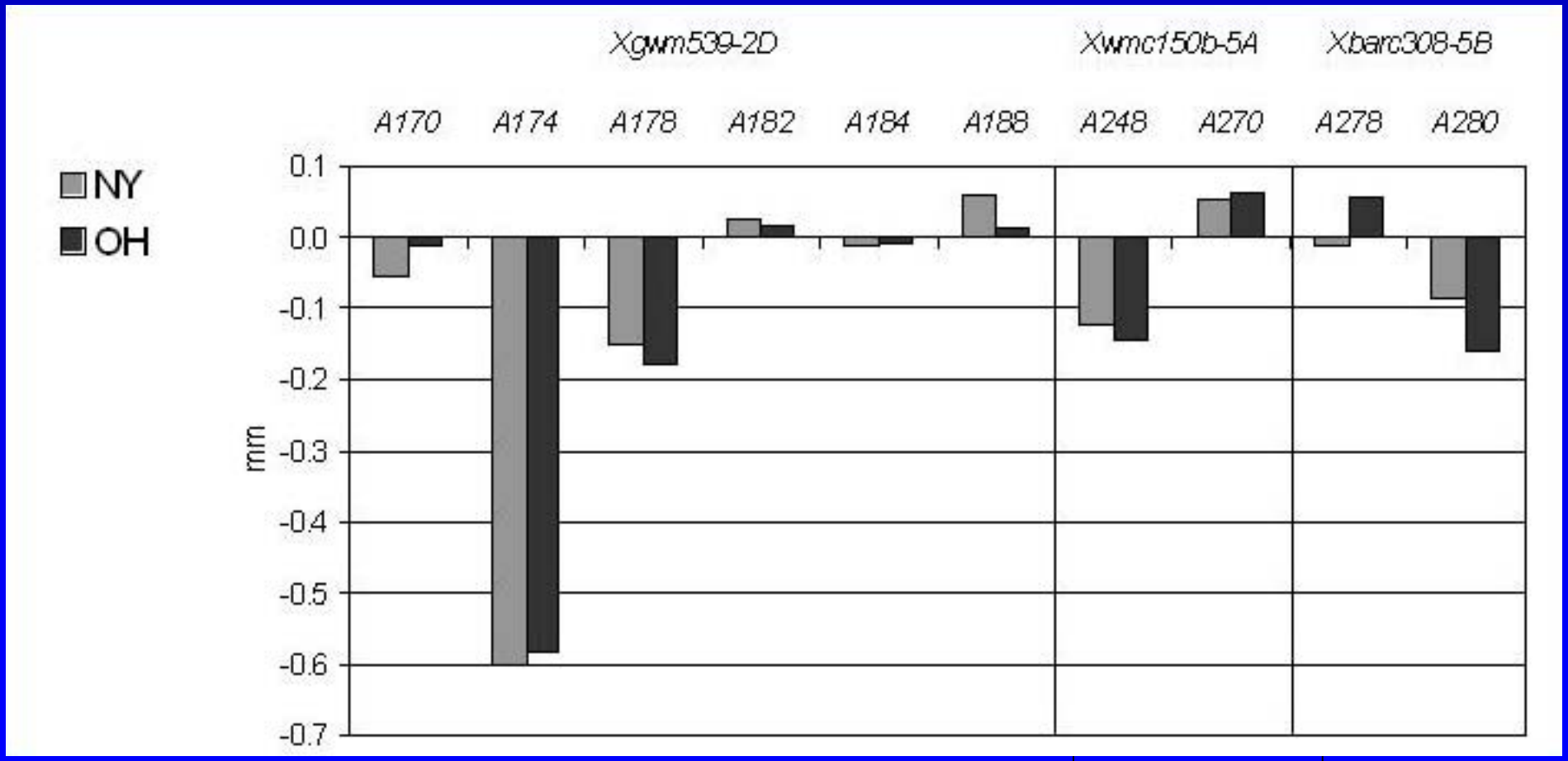
Locus		Weight		Area		Length		Width	
cM	Name	NY	OH	NY	OH	NY	OH	NY	OH
48	*Xcfa2121b*	0.785	0.053	0.525	0.039	0.289	0.245	0.290	0.005*
66	*Xbarc89*	0.651	0.110	0.791	0.118	0.518	0.159	0.003*	0.070
129	*Xbarc308*	0.041	0.000**	0.117	0.000**	0.461	0.001**	0.049	0.005*
134	*Xbarc232*	0.016	0.001**	0.005*	0.003*	0.064	0.002*	0.00	0.551

Milling Quality

cM	Locus	Milling Score	Flour Yield	ESI	Friability	Break-Flour Yield
130	*Xbarc142*	0.616	0.877	0.763	0.325	0.009*
134	*Xbarc232*	0.002*	0.005*	0.002*	0.003*	0.199

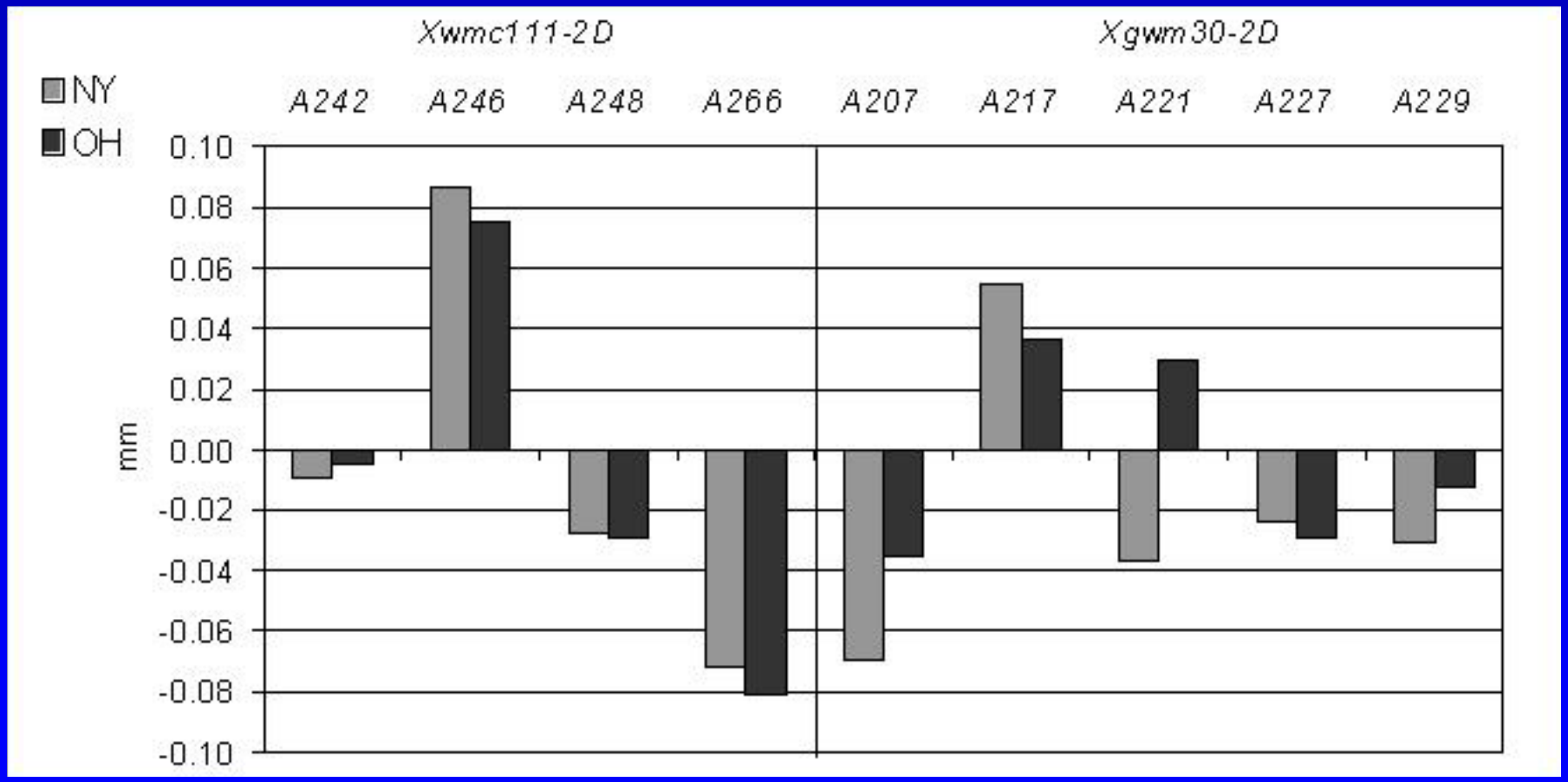
B.L.U.E. of allele effects
Kernel Length

N. of Cultivars: 9 5 18 37 9 9 41 45 43 49



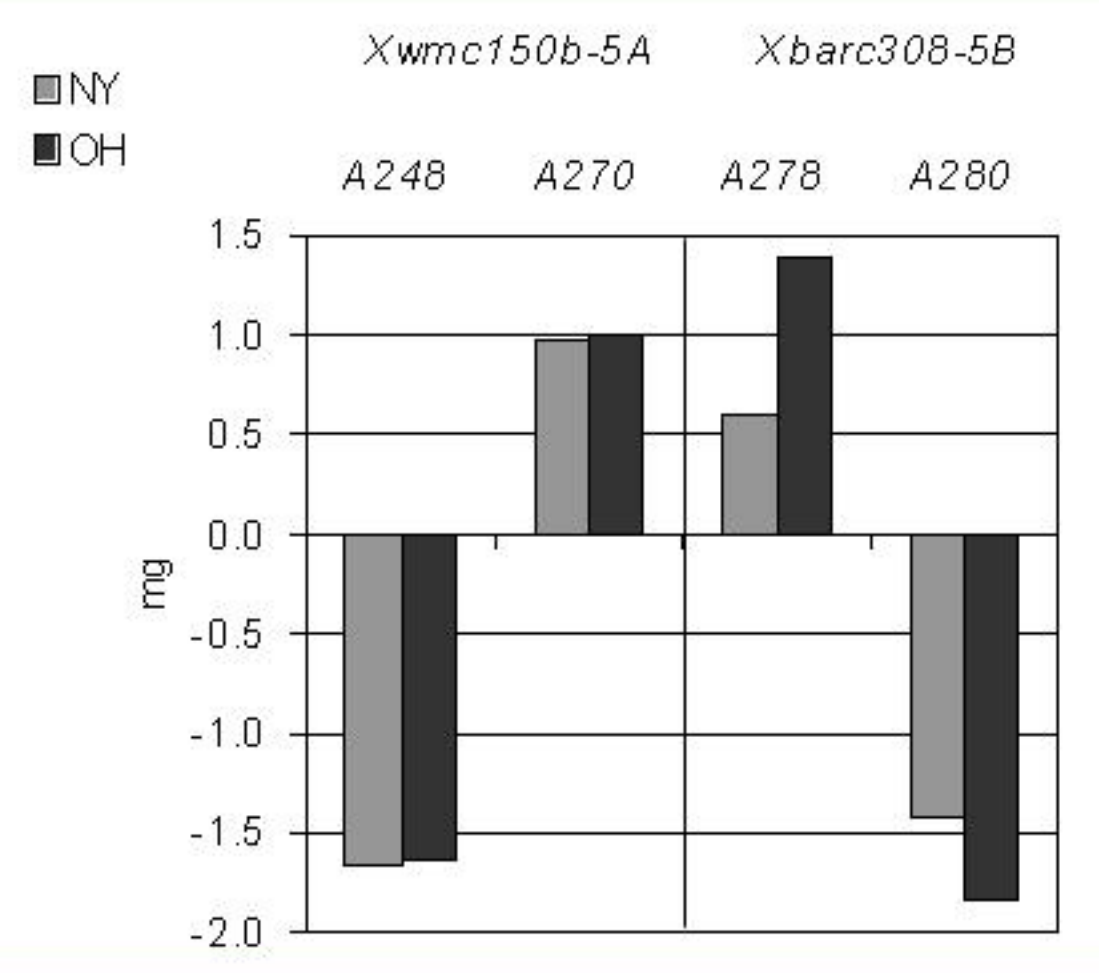
B.L.U.E. of allele effects
Kernel Width

N. of Cultivars: 41 14 8 15 18 24 5 10 19



B.L.U.E of allele effects
Kernel Weight

N. of Cultivars: **41** **45** **43** **49**



Conclusions

- Linkage Disequilibrium and Association Mapping
  - There is significant variation in LD across the genome and in different collections of genotypes
  - Markers closely linked to QTL of interest can be identified and allelic effects quantified
- Kernel Size and Shape and Milling Quality
  - Length and width are not strongly correlated.
  - Some QTL intervals are associated with both milling traits and kernel size and shape.
  - Further studies could focus on mapping QTL for kernel size uniformity and evaluating the relationship with the proportion of primary, secondary, and tertiary kernels AND grain yield.

Cornell Small Grains Breeding and Genetics Personnel

- M. E. Sorrells – Small Grains Breeder
- David Benscher - Research Support Specialist
- Gretchen Salm – Technical Field Assistant
- James Tanaka – Technical Assistant

- Post Doctorates:
  Jesse Munkvold
  Mahmoud Zeid

- Visiting Scientist
  Xuejun Li

- Fulbright Fellows
  Marc Moragues
  Ornubol Chamdej

- Grad Students
  Elliot Heffner
  Suthasinee Somyong
  Keith Williams

Acknowledgements

- USDA Soft Wheat Quality Lab, Wooster, OH
- Embrapa

Provided assistantship for Flavio Breseghello

- USDA Cooperative State Research, Education and Extension Service, Coordinated Agricultural Project

Technical support: David Benscher, James Tanaka, Gretchen Salm